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Physical Characteristics of Arctic Fox (*Alopex lagopus*) Dens in Northern Yukon Territory, Canada

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ABSTRACT. Physical characteristics of arctic fox (*Alopex lagopus*) dens on Herschel Island and the Yukon Coastal Plain, Yukon Territory, Canada, are described. The preferred den habitat on Herschel Island is characterized by moderately eroded, sloping, gullied terrain, where foxes select sandy erosional mounds for denning. The preferred habitat on the Yukon Coastal Plain is fluvial landforms, where foxes select streamside cutbanks and occasional dunes for den location. Dens are generally associated with relatively warm, well-drained landscape positions. Burrow entrances are significantly oriented toward the south ($P<0.0025$). Soils of dens are coarse textured, typically sandy loam to sand. Depth to permafrost is significantly greater under the den than at adjacent sites ($p<0.02$). Certain unique soil profile characteristics, particularly the replacement of common cryoturbation (frost churning) features with those of zooturbation (faunal mixing) and the formation of humus-rich surface horizons, appear to be the result of denning activities by foxes. Observed differences in soil temperature and depth to permafrost between den site soils and adjacent soils have likely been caused, at least in part, by denning activities.

Key words: arctic fox (*Alopex lagopus*), dens, soil characteristics, habitat, distribution, northern Yukon Territory

RÉSUMÉ. On décrit dans cet article les caractéristiques physiques des renardières du renard polaire (*Alopex lagopus*) sur l'île Herschel et sur la plaine côtière du Yukon, dans le Yukon, au Canada. Sur l'île Herschel, les renards préfèrent un terrain moyennement en pente, érodé et raviné, et ils choisissent des buttes d'érosion sablonneuses pour creuser leur terrier. Sur la plaine côtière du Yukon, ils préfèrent des modelés d'origine fluviale, où ils choisissent les rives découpées au bord des ruisseaux ou bien les rares dunes, pour creuser leur terrier. En général, les renardières se trouvent dans des endroits relativement tempérés et bien drainés. L'entrée des terriers est généralement orientée vers le sud ($P<0,0025$). Le sol des terriers a une texture grossière, allant typiquement du loam sableux au sable. Sous le terrier, le pergélisol commence à un niveau nettement plus profond qu'à des sites adjacents ($P<0,02$). Certains aspects uniques du profil du sol, en particulier le remplacement des caractéristiques ordinaires de la cryoturbation (brassage par le gel) par celles de la zooturbation (mélange biologique), et la formation d'horizons riches en humus à la surface, semblent être le résultat de la vie dans le terrier. Les différences de température du sol et de niveau du pergélisol observées entre les renardières et les sites adjacents semblent dues, au moins en partie, à la vie dans le terrier.

Mots clés: renard polaire (*Alopex lagopus*), renardières, caractéristiques du sol, habitat, distribution, nord du Yukon

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INTRODUCTION

Arctic foxes (*Alopex lagopus*) use dens for rearing of young and shelter (Eberhardt *et al.*, 1983). Dens have been estimated to be utilized for up to 300 years, often being enlarged, with additional entrances added in successive years until they deteriorate through natural processes (Macpherson, 1969). Arctic foxes often select historically preferred dens (Eberhardt *et al.*, 1983), with some evidence that individuals will return to the same dens in successive years (Eberhardt *et al.*, 1983). Although it is not yet known whether arctic fox populations are limited by the availability of suitable den sites (Macpherson, 1970), it seems obvious that the availability of suitable denning sites plays an important role in the reproductive performance of the species. Because dens are necessary for reproduction and are focal points of activity in summer, foxes are probably most susceptible to human disturbance during the denning season.

In the Yukon Territory, arctic fox breeding habitat is confined to the relatively narrow belt (0.5-24 km) of low-lying tundra comprising the Yukon Coastal Plain, bordering the Beaufort Sea and Herschel Island. The clumped distribution of arctic fox dens and their absence over vast area in northern Yukon Territory (Smits and Jessup, 1985) suggests that denning sites are limited. Den sites have also been shown to be vulnerable to destruction by off-road vehicles (Ruttan, 1974). Knowledge of the requirements for den sites is therefore critical for sound management of foxes in this northern ecosystem, especially in light of accelerating development of natural resources within this physiographic region. Additionally, classification of landscapes according to their suitability to sustain denning arctic foxes is crucial for multiple land use planning.

The purpose of the present study was to describe the physical and soil characteristics of fox dens in the northern Yukon Territory and to discuss den distribution relative to landform characteristics of the region.

STUDY AREA

The study area includes Herschel Island and the Yukon Coastal Plain (Fig. 1). Herschel Island (100 km^2) is composed of marine sediments that have been deformed and ice-thrusted into their present form (McKay, 1959; Bouchard, 1974). While these deformed marine sediments are predominantly fine grained, there are limited exposures of sand and gravel.

Differential erosion has led to the development of coarse-textured ridges existing within a landscape of otherwise fine-grained materials. Most of the surface is rolling upland at elevations ranging from about 60 to 180 m above sea level.

The Yukon Coastal Plain (Bostock, 1970) is an eastward extension of the Arctic Coastal Plain (Wahrhaftig, 1965) from north coastal Alaska, averaging 20 km in width. It slopes from a high point of 150 m above sea level northward to the Beaufort Sea coast and encompasses an area of approximately 3700 km^2. The surficial materials of the Yukon Coastal Plain have mixed origins, being derived from glacial and non-glacial processes. Morainic, lacustrine and fluvial deposits are most common. Active fluvial landforms (large deltas) predominate on the plain

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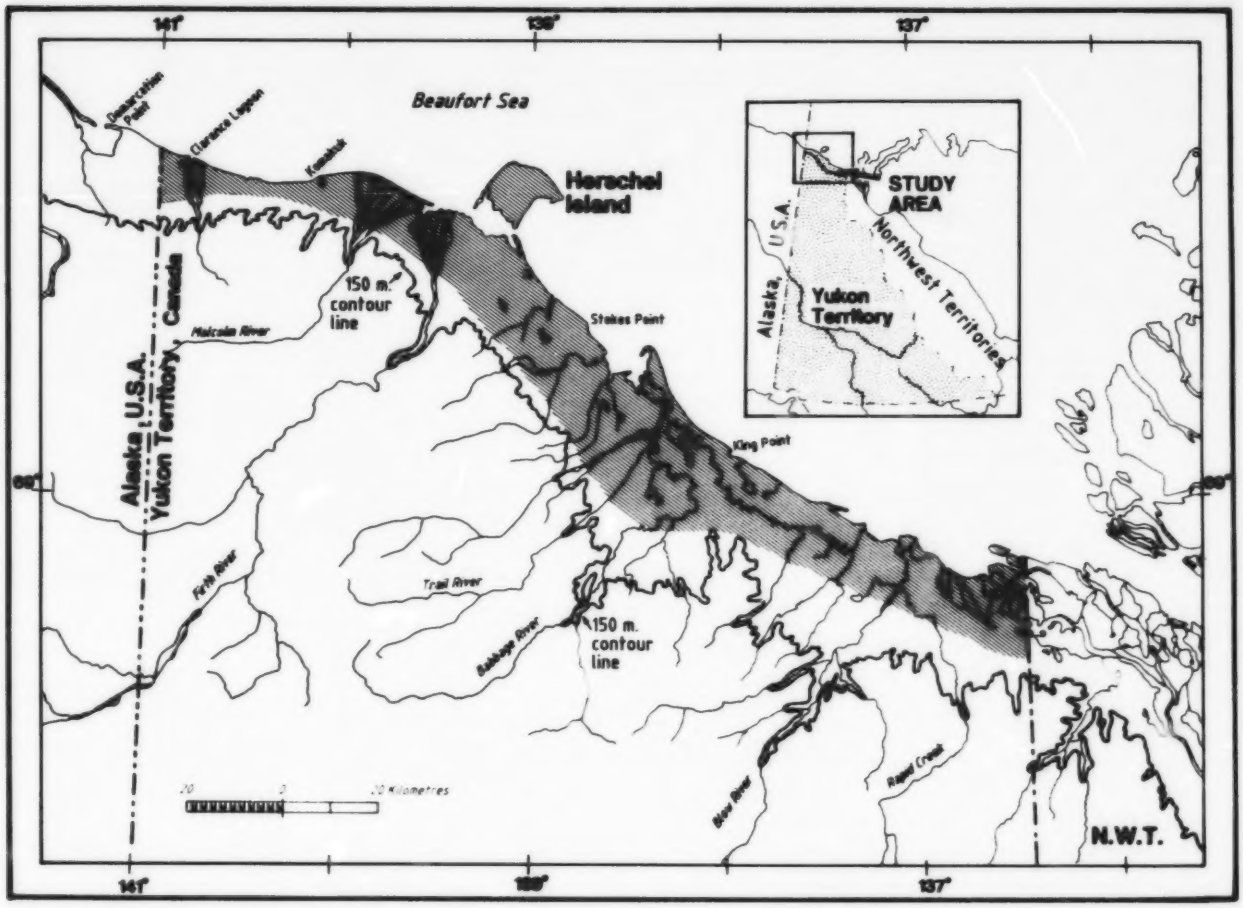

FIG. 1. Location of the study area (shaded), northern Yukon Territory, Canada.

west of Herschel Island. East of Herschel Island, the plain consists of rolling morainic deposits interspersed with nearly flat areas of lacustrine material. Lakes and ponds of thermokarst origin dot the plain, and local relief rarely exceeds 30 m (Rampton, 1982). The mean annual temperature at Komakuk is –12.1°C; the mean annual precipitation is 125 mm (Canadian Climate Program, 1982).

Cottongrass tussocks (*Eriophorum vaginatum*), moss, ericaceous shrubs and willows (*Salix* spp.) constitute the dominant vegetation on imperfectly drained upland sites in the study areas. On sites with better drainage avens (*Dryas integrifolia*), vetch (*Astragalus* spp.) and arctic willow (*Salix arctica*) predominate (Wiken *et al.*, 1981).

METHODS

Fox dens were located by searching the study area from a helicopter 3-10 July 1984, 29 June-14 July 1985 and 24-25 July 1986 (Herschel Island only). Transects were flown in a north-south direction on the Yukon Coastal Plain. They were spaced 400 m apart and flown 60-90 m above ground level at air speeds of 100-130 km·h^{-1}. The complete ground area was searched on Herschel Island using low air speeds (100 km·h^{-1}) and variable heights above ground level. Probable dens were identified by the color of the lush den vegetation, which contrasted with that of the surrounding area. Dens located from the air might be mistaken for wolf (*Canis lupus*) or ground squirrel (*Spermophilus parryii*) dens. To verify their identity, dens were checked on the ground for presence of arctic fox scats, tracks, hair and/or presence of arctic foxes.

Den sites were numbered and their locations plotted on a 1:25 000 map (Herschel Island, n = 34 dens) or a 1:125 000 map (Yukon Coastal Plain, n = 36 dens). Measurements were taken from randomly selected dens on Herschel Island (n = 17 dens) and Yukon Coastal Plain (n = 25 dens) of the surface area (length × width) of the den site and the maximum height of the mound. Surface profiles, position of den site on the landscape and aspect (of side of den with most burrow entrances) were recorded following Day (1983). Distribution of den aspects were analyzed using a V-test (Zar, 1984). The number of burrow entrances was counted and their height and width measured. Soil temperatures on the den site mound and at a site approximately 10 m from the den typical of the surrounding terrain were measured at a depth of approximately 8 cm. Differences between den characteristics of Herschel Island and Yukon Coastal Plain or between characteristics of dens and

Erratum. Section 1 (page 14, Results) should read:

Dens on Herschel Island have significantly larger burrow entrances (mean width = 19.8, S.D. = 5.1, mean height = 18.1, S.D. = 4.5; n = 130) than dens on Yukon Coastal Plain (mean width = 16.9, S.D. = 5.5, mean height = 15.3, S.D. = 4.2; n = 230) (two-sample t-test; for width, t = 4.1, df = 358, p < 0.001; for height, t = 41.0, df = 358, p < 0.0001).

those of adjacent sites were examined using two-tailed Student's t-tests.

A sample of 14 dens (10 on Herschel Island, 4 on Yukon Coastal Plain) representing the range of terrain conditions was examined for various soil characteristics. At each of these sites a soil pit was dug, usually slightly off to one side and away from any burrow openings. Pits were excavated through the den mound to permafrost. For comparative purposes a second soil pit representative of the surrounding landscape was dug at a site immediately adjacent to a sub-sample of dens (7 on Herschel Island, 3 on the Yukon Coastal Plain).

In order to characterize and classify the soils, the soil profile was described and a limited set of laboratory analyses was conducted on soil samples. Soils were sampled by horizons following the method of McKeague (1978) and classified according to Canada Soil Survey Committee (1978) and Soil Survey Staff (1975). All soil samples were air dried and seived, and the <2 mm fraction was used for laboratory analyses for organic carbon content, pH ($CaCl_2$), total nitrogen and particle size, following methods outlined by Sheldrick (1984).

RESULTS

Approximately half of the dens in the study area were located during systematic surveys as indicated by a subsequent survey (Smits and Slough, 1988).

Den Mound Characteristics

Heights of den mounds on Herschel Island (mean = 4.5 m, S.D. = 2.2, n = 17) are significantly greater than those of Yukon Coastal Plain (mean = 2.1 m, S.D. = 1.3, n = 24) (two-sample t-test $t = 6.5$, $df = 39$, $p<0.001$). Mean surface area of dens amounts to 123.1 m^2 (S.D. = 122.3, n = 17) on Herschel Island and to 130.1 m^2 (S.D. = 115.9, n = 25) on Yukon Coastal Plain. The average number of burrow entrances per den is 19.6 (S.D. = 13.7, n = 17) on Herschel Island and 18.7 (S.D. = 9.3, n = 25) on Yukon Coastal Plain. Dens on Herschel Island have significantly larger burrow entrances (mean width = 19.8 cm, S.D. = 5.1, mean height = 15.3 cm, S.D. = 4.2, n = 230) (two-sample t-test; for width, $t = 4.1$, $df = 358$, $p<0.001$; for height, $t = 41.0$, $df = 358$, $p<0.0001$).

Aspects of the side of the den with most burrow openings for all dens surveyed (n = 25 on Yukon Coastal Plain, n = 17 on Herschel Island) are not uniformly distributed in all directions (Raleigh's test, $z = 4.06$, $p<0.002$) but were strongly oriented in a southerly direction (mean aspect = 171°; V-test, $U = 2.81$, $p<0.0025$).

Soil Properties of Dens and Surrounding Landscapes

Dens on Herschel Island are associated with erosional features and hummocks, while on the Yukon Coastal Plain stream cutbanks, terrace escarpments, dunes and morainic ridges provide the required relief for den location. Dens are located on soils with sandy loam to sand textures and moderately well to rapid drainage (Table 1). The only exception is den 14, located on a soil with imperfect drainage. Mean soil temperature of dens on Herschel Island is 8.6°C, compared with 7.8°C for off-den sites. These values for dens on Yukon Coastal Plain are 9.4°C and 7.6°C respectively. When temperature values for dens and off-den sites on Herschel Island and Yukon Coastal Plain are combined, there is a significant difference between mean temperature of dens (9.0°C) and mean temperature of off-den sites (7.7°C) (paired-sample t-test $t = 2.3$, $df = 78$, $p<0.05$).

Soils of den sites on Herschel Island are usually quite different from those of the surrounding landscape. Within the landform units occupied by dens on Herschel Island, foxes select coarse-textured soils over the fine-textured soils that make up the majority of each landform. On the Yukon Coastal Plain, where large fluvial and glaciofluvial landforms are utilized, little textural difference between den and surrounding landscape is evident. Rather, local relief and the presence of ridges or hummocks influence den location. Mean depth to permafrost under combined Herschel Island and Yukon Coastal Plain dens is 72 cm, significantly different ($t = 32$, $df = 9$, $p<0.02$) from adjacent sites (44 cm) (Table 1).

Soils with permafrost within 1 m of the surface belong to the Cryosolic order in the Canadian soil classification system (Canada Soil Survey Committee, 1978). The most common fox den soils are classified as Orthic Static Cryosols. Only two soils examined do not fall into this order; these are classified as Regosols. Within the U.S. system of soil taxonomy all soils have Pergelic temperature regimes and belong to Cryic great groups of various suborders of the Entisol, Inceptisol and Mollisol orders, depending on the degree and sequence of horizon development. Most common fox den soils are classified as Pergelic Cryorthents (Soil Survey Staff, 1975).

DISCUSSION

The difference in mound sizes of fox dens between Herschel Island and the Yukon Coastal Plain reflects a difference in terrain between the two areas. Mounds are a characteristic feature of the erosional terrain of Herschel Island and are far less common on the level landscape of the Yukon Coastal plain.

Fox dens of the northern Yukon Territory are larger, with more complex burrow systems, than those reported for the Bolshezemelskaya tundra, U.S.S.R. (Danilov, 1961) and the Teshekpuk Lake area of northern Alaska (Chesemore, 1969). However, den sites of the Colville River delta in northern Alaska (geomorphically similar to the Firth River delta in this study) (Garrott *et al.*, 1983) are approximately twice as large, with twice as many burrow entrances. This variation in reported den sizes and complexity of burrow systems may be a function of the suitability of the terrain and soil for burrow construction, the fecundity of the arctic fox population in the area, the age of the den or use of the dens by other mammals.

Burrow entrance dimensions agree well with those reported by Sdobnikov (1960), Chesemore (1969) and Eberhardt (1977). The smaller average dimension values of the Yukon Coastal Plain may be the result of arctic ground squirrels using fox dens on the Yukon Coastal Plain. Arctic ground squirrels are known to occupy deserted fox dens and create additional, smaller burrows (Macpherson, 1969; Garrott *et al.*, 1983; pers. obs.).

The southerly orientation of the burrow entrances supports the contention that arctic foxes select for favourable microclimate conditions to construct dens (Danilov, 1961; Chesemore, 1969).

We observed the usual preference for warm and well-drained landscape positions for denning. The use of the streamside cutbanks and dunes characteristic of the fluvial landforms for denning, as recorded on the Yukon Coastal Plain, is a common phenomenon (Dementyeff, 1955; Danilov, 1961; Macpherson, 1969). On Herschel Island, where the classic fluvial, glaciofluvial

TABLE 1. Summary of landscape and soil characteristics of selected arctic fox den sites in northern Yukon Territory

Den ID no.	Site description	Soil texture[1]		Soil drainage[1]		Depth to permafrost (cm)		Classification of soil development on den mound[2]	
		Den site	Adjacent site	Den site	Adjacent site	Den site	Adjacent site	Canada	U.S.
Herschel Island									
1	erosional remnant mound at gully head	SL-LS	SiL[3]	Well	Imperfectly	105	25	Regosolic Static Cryosol	Pergelic Cryorthent
2	erosional remnant mound near coast	fS-SiL	SiL	Well	Imperfectly	110	60	Orthic Regosol	Pergelic Cryorthent
3	gravelly ridge exposed by moderate erosion	gLS	SL	Moderately well	Moderately well	45	39	Regosolic Static Cryosol	Pergelic Cryoboroll
4	sandy ridge exposed by moderate erosion	SL	CL	Well	Imperfectly	63	25	Regosolic Static Cryosol	Pergelic Cryoboroll
5	erosional remnant mound near gully head	SL	—	Well	—	—	—	Regosolic Static Cryosol	Pergelic Cryorthent
6	erosional remnant mound near steep coastal bluff	SL	—	Well	—	—	—	Regosolic Static Cryosol	Pergelic Cryorthent
7	plateau mound near coastal bluff	SL	SiCL	Moderately well	Imperfectly	63	57	Orthic Static Cryosol	Pergelic Cryaquept
8	hummock mound on rolling terrain	S-LS	SiL	Well	Moderately well	53	31	Regosolic Static Cryosol	Pergelic Cryosamment
9	mound of exposed mixed sediments	L/peat	—	Moderately well	—	—	—	Orthic Turbic Cryosol	Pergelic Entic-Ruptic Cryocrept
10	mound near patterned ground	LS	SiCL	Well	Imperfectly	50	30	Regosolic Static Cryosol	Pergelic Cryoboroll
Yukon Coastal Plain									
11	Eolian/Fluvial — mounds associated with sand dune complex	S	S	Rapidly	Rapidly	82	73	Regosolic Static Cryosol	Pergelic Cryosamment
12	Firth River delta-cutbank	LS	LS	Rapidly	Rapidly	105	95	Orthic Regosol	Pergelic Cryosamment
13	Firth River delta-cutbank	SL/S	—	Rapidly	—	—	—	Orthic Static Cryosol	Pergelic Cryocrept
14	silty fluvial fan-cutbank	SiL	S	Imperfectly	Imperfectly	40	6	Orthic Turbic Cryosol	Pergelic Ruptic Cryaquept
					$\bar{x}$	72	44		
					SD	27	27		

[1]Soil texture and drainage are according to Canada Soil Survey Committee (1978).
[2]Canadian soil classification is according to Canada Soil Survey Committee (1978); U.S. soil classification is according to Soil Survey Staff (1975).
[3]Soil texture classes: SL-sandy loam, LS-loamy sand, fS-fine sand, SiL-silt loam, S-sand, L-loam, gLS-gravelly loamy sand, SiCl-silty clay loam.

and eolian landforms are absent, the foxes select sandy erosional mounds. One den was observed on a mound associated with patterned ground (non-sorted circles), and numerous small dens (apparently non-natal) were observed on pulsa mounds set within polygonal wetland areas on the level upland tussock tundra of Herschel Island. It seems clear that landforms control the distribution of den sites.

Foxes transport nutrients, both directly (carcasses) and indirectly (scats and urine) to the den site, thereby increasing the soil fertility at the den site as reflected in a lush vegetation cover relative to surrounding tundra. Foxes tend to mix materials through burrowing, bringing fresh material to the surface and burying organic materials. Many soil profiles contain bones at all depths. Soil profile characteristics, particularly the replacement of cryoturbation (frost churning) features with those of zooturbation (faunal mixing) and the formation of humus-rich surface horizons, are likely the result of denning activities. On Herschel Island these soils are most often classified as Static rather than Turbic Crysols (Canada Soil Survey Committee, 1978). Surface horizon enrichment leads toward the development, in extreme cases, of Pergelic Cryoborolls (Soil Survey Staff, 1975), a soil taxa relatively rare elsewhere on the island. On the Yukon Coastal Plain soil taxa associated with fox den sites are not unlike those of the surrounding landscape. Within both physiographic areas, soil taxa *per se* are not necessarily definitive in terms of identifying fox den habitat but are extremely descriptive in characterizing the den ecosystem.

The higher soil temperatures of arctic fox dens relative to off-den sites is a common phenomenon of den sites (Danilov, 1961; Chesemore, 1969) and may be related simply to the coarser texture of den soils. It is not clear whether den sites are inherently warmer than nearby sites before foxes start constructing the dens, or if the favourable soil thermal regime and the lowering of the permafrost table on den sites result from the presence of burrows, which act as ventilation ducts. In most cases, observed conditions probably result from a combination of inherent and altered factors. Certain soil properties (well drained, coarse textured) that make fox den soils distinct from those surrounding the den are little altered by fox activity. These inherent soil properties no doubt contribute to the initial selection of the site for denning.

MANAGEMENT CONSIDERATIONS

The arctic fox is adaptive and opportunistic in den site selection. When the classic coarse-textured landforms (dunes, fluvial deposits) are not present, the foxes will use any other micro-climatically suitable landscape feature. Foxes select den sites where relatively dry conditions prevail, whether these be found on the erosional mounds and ridges of Herschel Island,

the fluvial landforms of the Yukon Coastal Plain or even rock crevices, such as reported by Østbye *et al.* (1978) for bedrock-dominated landscapes in Norway. As such, it is not possible to state in absolute terms a set of universal terrain conditions required for den establishment. Rather, it emphasizes the need to develop associations of den locations with landforms, and where available cartographic units presented on terrain maps, in order to assess regional denning habitat.

Our observations indicate that it is not appropriate to extrapolate associations beyond the boundaries of one physiographic region or to attempt to base habitat capability on soil taxa alone, regardless of the taxonomic system followed. Associations developed for Herschel Island would not apply to the mainland, but those developed for the Yukon Coastal Plain would likely be applicable to the contiguous Arctic Coastal Plain of Alaska. The non-random association of den locations with certain landforms might allow the use of terrain maps of various scale and composition to rank the potential importance of landscapes for fox denning. This ability to rank landscapes facilitates the use of existing terrain maps to assist in identifying areas where arctic fox dens are likely to be located.

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